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SOUTHERN NEW BRUNSWICK POTENTIAL FIELD PROJECT, PART I: IMPLICATIONS FOR GRANITE-RELATED GOLD MINERALIZATION IN THE CLARENCE STREAM AREA

M.S. King, P.Geo. and S.M. Barr

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Southern New Brunswick Potential Fields Project, Part I: Implications for Granite-related Gold Mineralization in the Clarence Stream Area

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New Brunswick Department of Natural Resources and Energy

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April 2003

Abstract

New petrographic and gravity measurements have been combined with existing aeromagnetic and gravity data in southern New Brunswick to model the subsurface distribution of granitic bodies related to gold mineralization in the Clarence Stream area. The Magaguadavic Granite phase of the Saint George Batholith is shown to be a spatially extensive, moderate- to high-amplitude, positive magnetic feature in the near surface. At depth, this magnetic response becomes limited to a small area in the southern part of the granite and corresponding gravity data reveals a pronounced gravity low beneath the northern half of the granite. These data suggest the presence of a more felsic granitic phase emplaced in the subsurface into the northern portion of the Magaguadavic Granite and extending beneath the satellite plutons to the north. This more felsic phase of the Magaguadavic Granite may represent a more fractionated component of a long-lived magmatic and hydrothermal system that generated gold mineralization at various depths along the northern margin of the Saint George Batholith.

Résumé

On a combiné de nouvelles mesures pétrographiques et gravimétriques à des données aéromagnétiques et gravimétriques existantes du Sud du Nouveau-Brunswick pour modéliser la distribution de subsurface des masses granitiques apparentées à une minéralisation aurifère dans le secteur du ruisseau Clarence. La phase du batholithe de Saint George du granite de Magaguadavic a l'aspect d'une particularité magnétique positive, de moyenne à grande amplitude, spatialement étendue dans la zone de subsurface. En profondeur, cette réponse magnétique devient limitée à un petit secteur dans le sud du granite, et les données gravimétriques correspondantes révèlent un creux gravimétrique prononcé au-dessous de la moitié septentrionale du granite. Ces données laissent supposer la présence d'une phase granitique plus felsique ayant pénétré la zone de subsurface de la partie septentrionale du granite de Magaguadavic et se prolongeant au-dessous des plutons satellites au nord. Cette phase plus felsique du granite de Magaguadavic pourrait représenter une composante plus fractionnée d'un système hydrothermal et magmatique de longue durée qui a produit une minéralisation aurifère à diverses profondeurs le long de la limite septentrionale du batholithe de Saint George.

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1.0 Introduction

This project was conducted under the auspices of a collaborative research agreement between the New Brunswick Department of Natural Resources and Energy and Acadia University (principle investigator Sandra M. Barr). It forms part of an on-going geological research programme in southern New Brunswick by the second author.

1.1 Project Scope

The geology of southern New Brunswick is characterized by complex structural and stratigraphic relationships at both regional and detailed scales. Recent acquisition of high quality, high-resolution aeromagnetic data over the St. Stephen area provides valuable insight into several geological phenomena. Furthermore, existing high-resolution magnetic surveys around the Saint John area, complemented by archived gravity data, provide useful information regarding the regional structure and stratigraphy of southern New Brunswick.

Optimum utilization of existing potential field information requires that available data sets be compiled, and related to corresponding geology via a database of representative physical properties (i.e. density and magnetic susceptibility). In addition to generating an extensive physical property data set, this project identified the need for new gravity measurements in specific areas to improve potential field modeling.

The geographic scale of this project was such that regional issues were separated from more local geological issues, and this aspect of the project was designed to assess local themes with current exploration implications (e.g. Clarence Stream gold deposit).

However, in order to put the exploration implications of regional geophysical databases in context, a general introduction and discussion of the Southern New Brunswick Potential Fields Project and all data compiled and collected will precede the interpretation section, which is specifically related to gold mineralization in the Clarence Stream area.

1.2 Project Objectives

The objective of the Southern New Brunswick Potential Fields Project was to compile existing aeromagnetic and gravity data and to supplement these data sets with new petrophysical and gravity measurements. These data were then used to construct potential field models to investigate geological phenomena in three dimensions.

The results of the Southern New Brunswick Potential Fields Project are described in two separate reports, which are summarized as follows:

1) Part I: Implications for Granite-related Gold Mineralization - whereby enhancement of new and existing data combined with a 2 and ¾-D* potential field model were used to assess the sub-surface distribution and character of granitoid bodies in the Clarence Stream area. Regional structure and stratigraphy were also investigated.
2) Part II: Implications for Tectonic Analysis - whereby several regional transects were evaluated through two dimensional (2-D) potential field models in order to investigate the sub-surface extent and interrelationships of distinct lithostratigraphic belts. This task was supported by i) compilation of regional gravity and magnetic data, ii) acquisition of new gravity data and iii) physical property measurements (i.e. density and magnetic susceptibility) of several

thousand samples from the study area, archived at Acadia University in Wolfville, Nova Scotia.

This report provides specific details on Part I through a description of the data processing and enhancement, new data acquisition, physical property compilation, potential field modeling, and resulting interpretations. Part II is described in a separate report (King and Barr in press).

** 2 and ¾ -D potential field models are constructed using bodies with limited strike extent and varying physical properties off-section. These differ from 2-D models where a body is assumed to be isotropic and have infinite strike extent.*

1.3 Regional Geology

Southern New Brunswick is comprised of several distinct lithostratigraphic belts or terranes that have been intruded by extensive Silurian - Devonian plutons (Fig. 1). Younger Devonian - Carboniferous cover sequences are also prominent in the study area. The best documented terranes in the study area are (from southeast to northwest):

1. Caledonia terrane - a composite terrane comprised of Late Neoproterozoic rocks (Barr and White 1999) similar to the Avalon terrane throughout the northern Appalachian orogen. These rocks consist mainly of metasedimentary and metavolcanic rocks and associated granitoid rocks (ca. 620 Ma). Younger (560-500 Ma) volcanic and sedimentary rocks also occur throughout the belt and dominate the western highlands. These rocks were thought to have formed in a continental-margin arc setting with some younger units (e.g. Coldbrook Group) deposited in a subsequent extensional regime (Barr and White 1999).

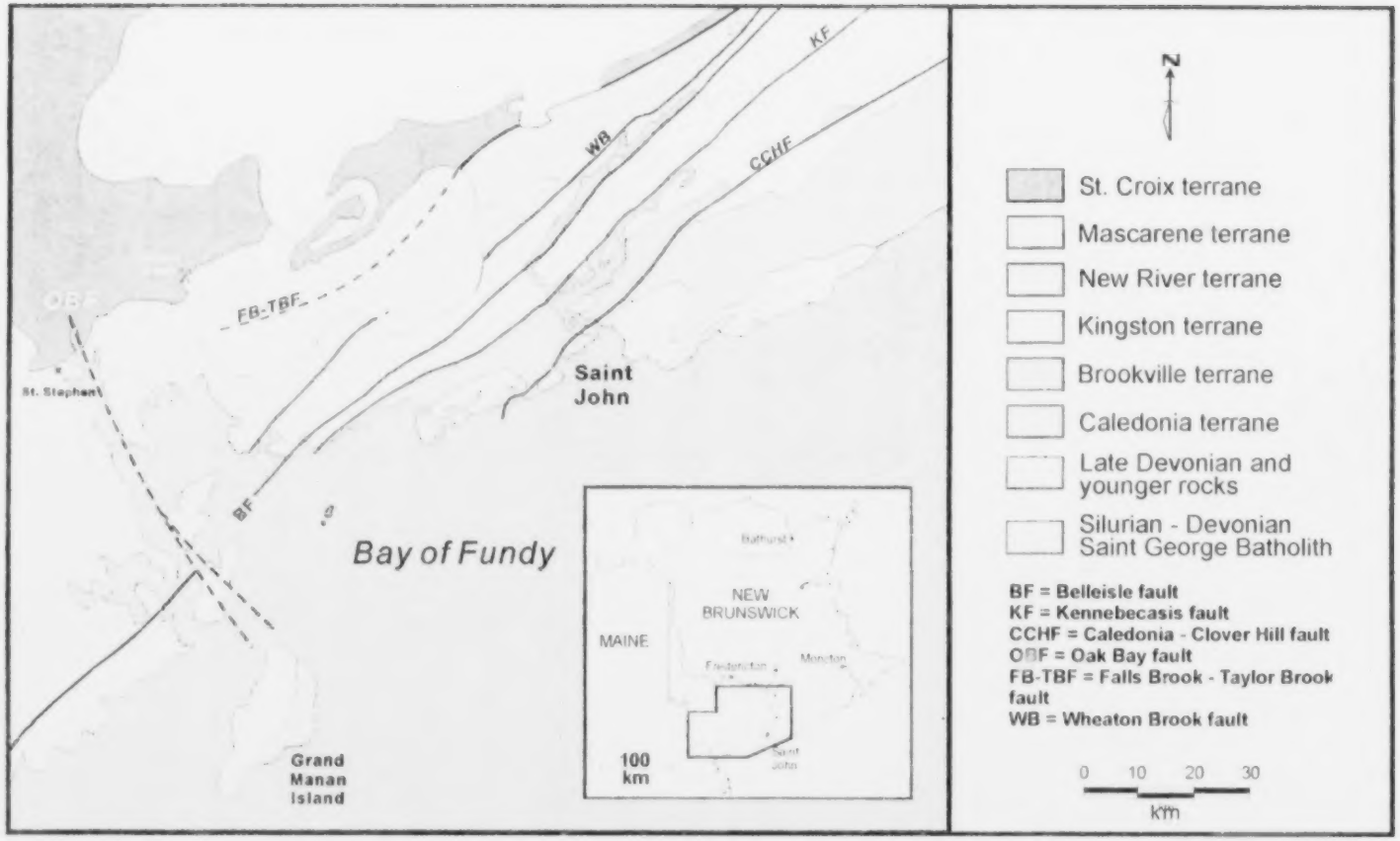

Figure 1. General location map showing major lithostratigraphic subdivisions in southern New Brunswick. Modified after Barr and White 1998.

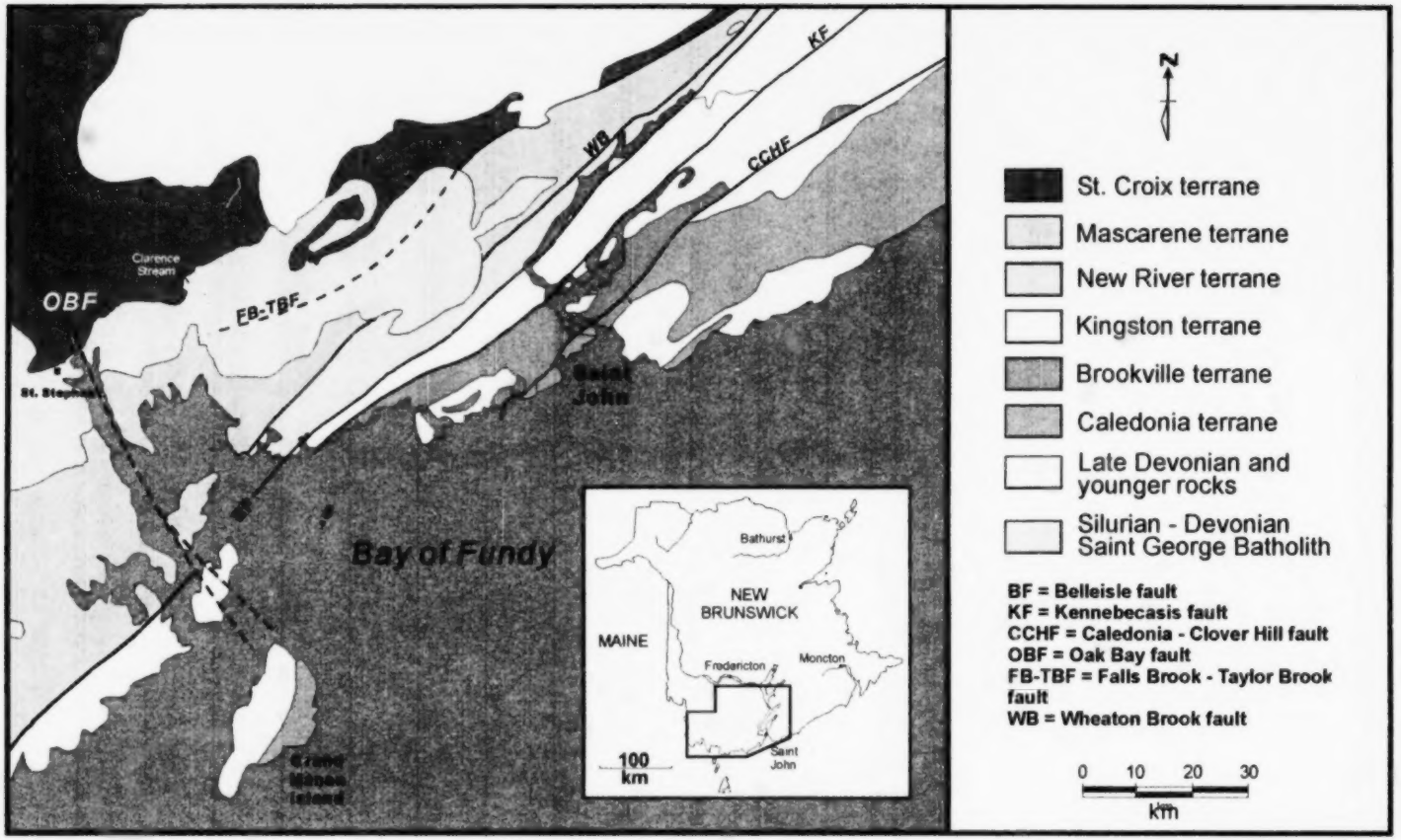

Figure 1. General location map showing major lithostratigraphic subdivisions in southern New Brunswick. Modified after Barr and White 1998.

2. Brookville terrane - a Proterozoic - Cambrian sequence of metasedimentary, metavolcanic, and gneissic rocks intruded by younger mafic and ultramafic rocks (Barr and White 1996; White et al. in press, Samson et al. 2000). The metasedimentary rocks consist of marble-dominated units (Ashburn Formation) and metasiltstone-dominated units (Martinon Formation). The Brookville Gneiss is comprised mainly of paragneiss (~ 640 Ma) with minor orthogneiss (~605 Ma). Plutons ranging in composition from diorite to granite have been dated at 550 Ma to 527 Ma (U-Pb) and have petrological characteristics that suggest that they were emplaced in a continental margin subduction zone (White et al. in press; Samson et al. 2000).
3. Kingston terrane - a sequence of Silurian metavolcanic and granitoid rocks intruded by abundant mafic dykes (Barr and White 2001). Barr et al. (2002) proposed a model for the Kingston Group and related granites whereby these rocks formed in an arc setting on the margin of Ganderia. Late Silurian extension (cf. Coastal Maine magmatic province) may have been responsible for the emplacement of mafic dykes (Barr et al. 2002).
4. New River terrane - a structurally complex assemblage of Neoproterozoic and Cambrian sedimentary and mafic to felsic igneous rocks likely formed in an arc setting (Samson et al. 2000; Johnson 2001, 2003). Neoproterozoic granitoid rocks cover a wide range of lithologies, including leucogranite, granodiorite, tonalite, syenogranite, quartz-diorite, and gabbro, and have ages of ca. 620 Ma and ca. 550

- 540 Ma (Johnson 2001, 2003). The relationship of these units to rocks of similar age in the Caledonia and Brookville terranes is debated (e.g. Johnson 2001; White et al. in press).

5. Mascarene terrane - a cover assemblage of siliciclastic sedimentary and volcanic rocks deposited over the New River – St. Croix terrane boundary during the Silurian to Early Devonian (Fyffe and Fricker 1987; Fyffe et al. 1999). Strata in the Mascarene terrane occur in distinct fault-bounded blocks related to later transpressional tectonic events.
6. St. Croix terrane - a sequence of Cambro-Ordovician to Silurian sedimentary and very minor volcanic rocks (Fyffe and Fricker 1987; Fyffe et al. 1999). The St. Croix terrane is dominated by sedimentary rocks characteristic of a passive continental margin; however, the presence of volcanic rocks and changes in types of sedimentation also indicate a possible evolution into a more active margin setting (van Staal and Fyffe 1995). These rocks are associated with the Gander terrane (van Staal et al. 1998) and presumably were deposited along the eastern margin of the Iapetus Ocean (cf. Whalen at al. 1996).

These terranes were amalgamated by the latest Silurian and intruded by numerous Late Silurian (e.g. Welsford Complex, ca. 422 Ma; Utopia Granite, ca. 418 Ma), Early Devonian (e.g. Magaguadavic Granite, ca. 396 Ma); Late Devonian (Mount Douglas Granite, ca. 367 Ma) plutons, comprising the Saint George Batholith (McLeod 1990; McLeod et al. 1994). This spatially extensive batholith comprises nearly 50% of the study area. Temporal evolution from mafic-felsic (e.g. Bocabec, Utopia) to felsic (Mt.

Douglas Granite, Mount Pleasant Porphyry) compositions has also been documented (e.g. McLeod 1990; McLeod et al. 1994). The evolution from mafic to felsic compositions is reflected in regional potential field data and will be discussed in more detail in this report.

1.4 Local Geology

The Clarence Stream gold deposit is located in the western portion of the project area approximately 28 kilometers northeast of St. Stephen (Fig. 1). Recent exploration activity in the Clarence Stream area by the deposit owner Freewest Resources Canada Incorporated has exposed more bedrock and allowed revision of geological relationships in the area (e.g. Fyffe 1997; McLeod et al. 1998; Thorne and Lentz 2001; Thorne et al. 2002).

The main zone of the Clarence Stream gold deposit occurs along the northwest margin of the Magaguadavic Granite (Fig. 2) within east-northeast-trending shear zones (Thorne and Lentz 2001; Thorne et al. 2002). More recently discovered mineralized zones to the northeast of the main showing (Anomaly "A") also occur in brittle northwest-trending fault zones (Watters and Castonguay, 2002). The close spatial association of auriferous sulfide-bearing quartz veins with granitic dykes and local felsic plutons has lead authors to invoke an intrusion-related genetic model (Thorne and Lentz 2001; Thorne et al. 2002).

Gold mineralization at Clarence Stream occurs on both sides of the Sawyer Brook Fault, which separates Ordovician rocks of the St. Croix terrane to the north from Silurian rocks of the Mascarene terrane to the south (e.g. Fyffe 1997). Mineralization in the main

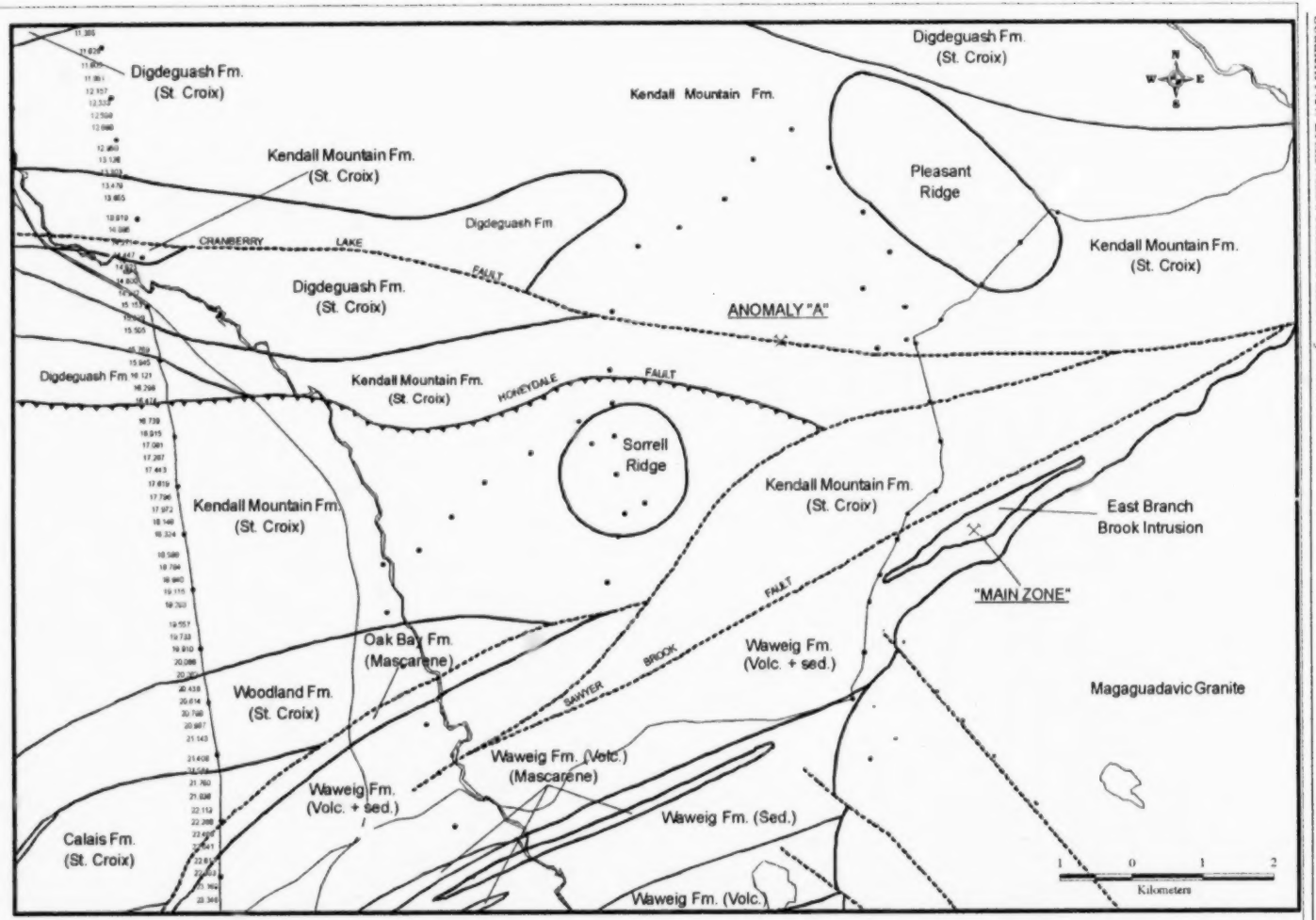

Figure 2. Geology map for Clarence Stream area after Fyffe (1997) and McLeod et al. (1998) showing new gravity stations and potential field model location with respect to mineralized zones.

zone is located within the contact aureole of the Magaguadavic Granite, which forms the northwestern part of the Saint George Batholith. The main zone is hosted in Silurian metasedimentary rocks of the Waweig Formation (Mascarene Group; McLeod et al. 1998) and multiple dykes that comprise the East Branch Brook metagabbroic intrusion (Thorne and Lentz 2001). Anomaly "A" is hosted by Ordovician sedimentary rocks of the Kendall Mountain Formation (Cookson Group) and occurs along a trend between the satellite Sorrel Ridge and Pleasant Ridge plutons (McLeod 1990; Watters and Castonguay 2002).

The close association of gold occurrences at Clarence Stream to granite bodies and brittle-ductile shear zones are the primary regional exploration criteria. High-quality regional potential field data are ideally suited to identifying these features.

2.0 Gravity Data

2.1 Archived Data

Two Bouguer gravity anomaly data sets were compiled as part of the initial investigation of potential field data for southern New Brunswick. The largest data set is a digital compilation by Hassan (2000) released by the New Brunswick Department of Natural Resources and it contained in excess of 23,000 points. A second digital data set consists of 157 stations that were acquired by Thomas and Willis (1989) during a gravity modeling study of the Saint George Batholith.

Hassan (2000) included industry and government data collected over 30-40 years throughout New Brunswick. This data was collected using various equipment and survey

specifications and is subject to significant error (L. Petrie 2002, pers. comm.). A review of the digital point data indicated some obvious, but isolated, erroneous stations that were deleted prior to processing. A sub-set covering southern New Brunswick was extracted for the purposes of this project (Fig. 3).

Gravity stations presented in Thomas and Willis (1989) were collected specifically for the purpose of generating 2-D gravity models examining the three-dimensional character of the Saint George Batholith. This information was intended for regional interpretation and hence stations were not positioned according to rigid industry standards. However, a review of the data indicated that this information was well suited to the present study and appear to be at least as good as most of the data in Hassan (2000). The Thomas and Willis (1989) stations shown in Figure 3 were merged with Hassan (2000) for comparison. Bouguer values from adjacent (5-50 m) stations showed only small differences, ranging from 0.02 – 0.86 mGal. Regional interpretations are generally limited to anomalies of 1 mGal or greater (i.e. typical contour interval). Consequently, it was deemed feasible to acquire more gravity data in select areas using field procedures similar to those presented in Thomas and Willis (1989).

2.2 Gravity Survey

Several areas within the scope of the investigation, identified during the compilation of gravity data and review of potential geological targets, had little or no gravity coverage. Therefore, a small field program was designed to collect "regional-scale" Bouguer gravity data at 500 – 1200 m spacing. This survey focused on selected regional transects and the area surrounding the Clarence Stream gold deposit (Fig. 3).

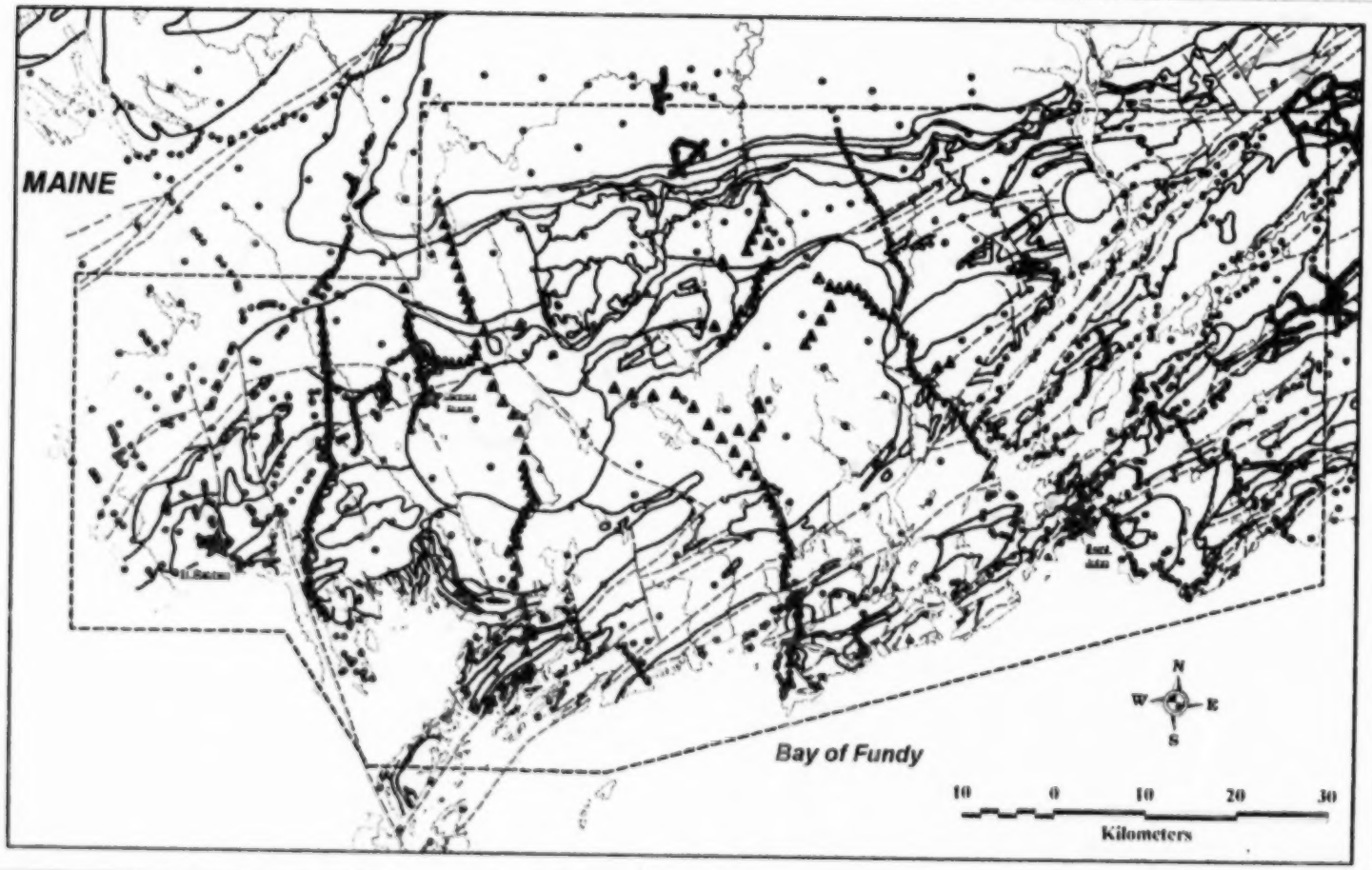

Figure 3. General location map showing compiled gravity stations. Green crosses = Hassan (2000); Blue triangles = Thomas and Willis (1989); Red circles = this study. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

Gravity surveying commenced on the 17th of September 2002 and ended on the 28th of September 2002. The survey was based out of Saint John, New Brunswick, using the Canadian Gravity Standardization Network (CGSN) base station at Martello Tower (#9161-1973) as the primary reference control. This provided several advantages, primarily by allowing each day to be executed as a complete and independent loop tied to the National Gravity Network.

The gravity instrument was a Scintrex CG-3M automated gravimeter. This instrument corrected daily variations for tide and instrument drift based on user-entered parameters. All general field procedures and reduction techniques to compute Bouguer anomalies (e.g. latitude, free-air, and Bouguer corrections) were in accordance with industry practices (e.g. Telford et al. 1988; Hassan 2000). Each survey day started at the CGSN station, where the hand-held GPS and barometric altimeter were also calibrated. Gravity stations were captured using GPS positioning (~6-10 m, X-Y) and barometric altimetry (+/- 1 m, Z). Altimeter data were checked post-processing against digital elevation models, known elevation monuments, and data contained in archived gravity files. Repeats were also made in each daily traverse to check gravimeter and altimeter data within the survey areas. Daily loops were completed at the CGSN base in Saint John. Gravity repeats and checks indicated excellent survey quality with differences in repeat measurements typically less than 0.05 mGal; however, whereas the accuracy of observations was high, the final accuracy of derived Bouguer anomalies was limited by the accuracy of the elevation measurements. Typically, the accuracy was estimated to be +/- 1 meter leading to a potential error of +/- 0.19 mGal (Bouguer density = 2.67 g/cm^3)

in the Bouguer anomaly; however, a conservative estimate of ~0.5 mGal RMS was utilized when interpreting final data (e.g. modeling error-of-fit). This accuracy level was consistent with the survey design and desired interpretational threshold (see Section 2.1). A total of 351 stations including repeats were recorded over the survey period (Fig. 3) and the raw data is presented in Part II of the project (King and Barr, in press).

2.3 Processing

Gravity readings for the Southern New Brunswick Potential Fields Project were compiled from an edited version of Hassan (2000), from Thomas and Willis (1989), and from that collected specifically for this project. Data were merged into a single database containing UTM X, UTM Y, elevation and Bouguer gravity values. All data were reduced using the international gravity formula (IGSN71) and a Bouguer density of 2.67 g/cm^3.

The distribution of points in regional data sets is somewhat problematic, specifically when establishing an appropriate grid cell size for creating map images. A 250 m cell size was chosen to generate spatially continuous gridded images for this project. Blanking distances of 2500 m from an observation point were specified to prevent extrapolation into areas without gravity stations. These areas appear as small white regions in the total field and residual colour contoured map images.

The final colour contoured Bouguer gravity anomaly map for the survey area generated from approximately 5700 stations is shown in Figure 4. Magenta-red colours correspond to higher positive values and blue-cyan colours correspond to lower negative values in each of the geophysical images presented in this report.

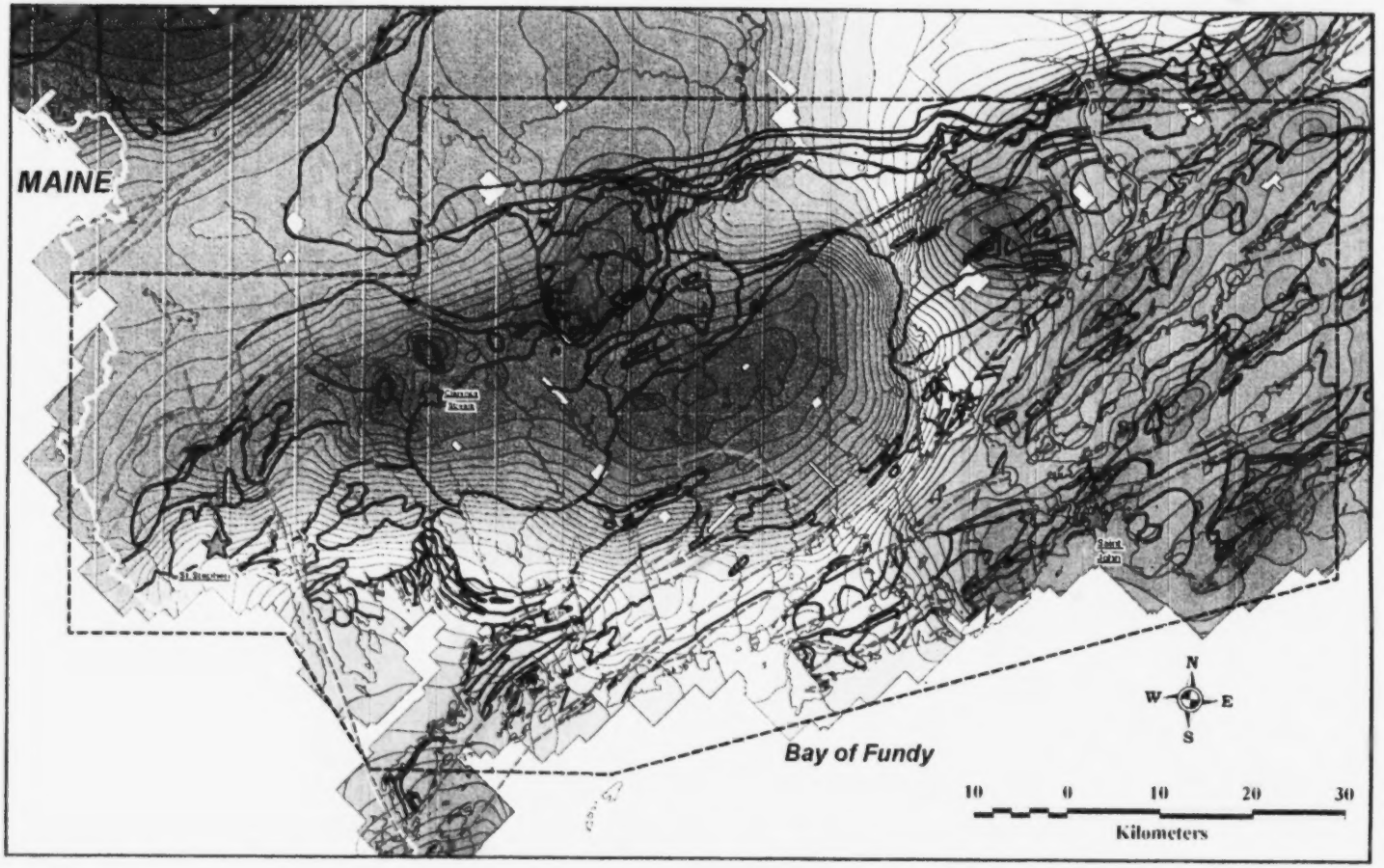

Figure 4. Colour contoured total field Bouguer gravity with 2 mGal contour interval. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

2.4 Enhancement

Potential field data may be thought of as composite measurements in that any particular data point contains the geophysical response from many kilometers of sub-surface material. Significant geological information can be garnered by enhancing near-surface features at the expense of deeper features by regional-residual separation techniques. The simplest techniques involve the removal of regional trends (i.e. long wavelength map patterns). This is a procedure whereby a polynomial surface is calculated to best fit the measured, gridded total field data. This trend or grid is then subtracted from the original total field data to produce a residual data set. The order of the polynomial surface can vary depending on the wavelength of the data that is to be highlighted. The subtraction of a low-order polynomial surface generates a grid that contains short to moderate wavelength features corresponding to bodies at shallow to moderate depths. This procedure was applied to the observed Bouguer anomaly grid (Fig. 4) to produce the residual grid shown in Figure 5. The map patterns in Figure 5 better highlight individual anomalies and more accurately present the relative responses of individual features. The subtraction of higher order polynomial trends produce more detail in gravity map patterns (i.e. short wavelength); however, these data were not presented in this report because of objectives and time constraints.

Wide spacing and irregular distribution of gravity stations in the study essentially limits interpretation to regional-scale features (e.g. 1-10 km). Many other enhancement techniques (e.g. vertical derivatives) are applicable to potential field data sets; however, they only work well on data collected along regularly spaced grids or flight lines.

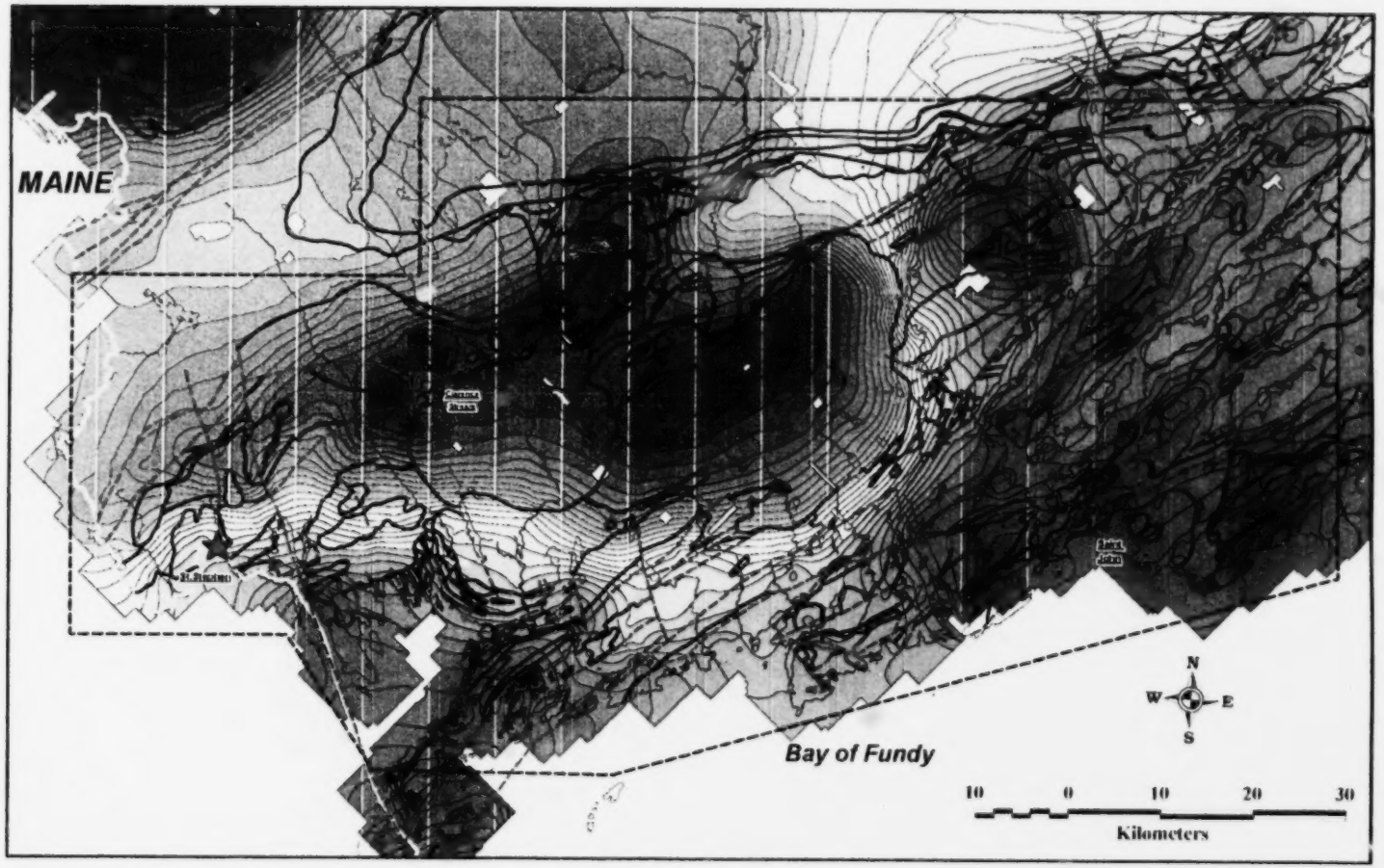

Figure 5. Colour contoured residual Bouguer gravity with 2 mGal contour interval. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

3.0 Aeromagnetic Data

3.1 St. Stephen and Saint John Surveys

The Geological Survey of Canada (GSC) acquired two high-resolution aeromagnetic data sets in southern New Brunswick. These data provide an extremely detailed, continuous magnetic image of the study area.

Fugro Sial Airborne Surveys Inc., using a fixed wing platform, completed the St. Stephen survey between October 21, 2001 and December 12, 2001. Flying height was 100 m along lines spaced 200 m apart oriented 144°/324° for a total of 26,800 km, including control lines. The leveled magnetic total field data were archived in a digital ASCII format.

Kenting Earth Sciences International, using a fixed wing platform completed the Saint John survey between October 7, 1987 and November 13, 1987. Flying height was 150 m along lines spaced 300 m apart oriented 135°/315° for a total of 13,524 km, including control lines. The leveled magnetic total field, measured vertical gradient and VLF data were archived in a digital ASCII format.

The GSC provided all airborne data to the authors on August 20, 2002 in digital ASCII XYZ format using the UTM NAD27 (Zone 20) coordinate system.

3.2 Processing

The compilation of the regional aeromagnetic data involved the merging of the St. Stephen and Saint John surveys. These data were collected using different survey parameters that influence the spatial resolution and amplitude of the measured response.

The St. Stephen survey was flown at 100 m, thereby providing greater along-line spatial resolution and higher amplitude measured response. Conversely, while still considered a high-resolution survey, the Saint John data were acquired at 150 m mean terrain clearance, which by comparison would reduce amplitudes, and along-line spatial resolution. The flight line spacing was 200 m (St. Stephen) versus 300 m (Saint John), which affects cross-line resolution.

Typically when aeromagnetic surveys are merged data acquired at the lower altitude are upward continued to the highest nominal altitude, effectively reducing the resolution of the "high-resolution" survey and hence defeating the purpose. In order to preserve the resolution of the St. Stephen survey the St. John survey data were merged by using a scaling factor derived from a statistical analysis of overlapping survey data. In this manner the highest quality data are preserved and relative amplitudes are partially leveled. The Saint John data were multiplied by a scaling factor of 1.024435 resulting in a point-by-point fit with the St. Stephen survey (i.e. overlapping areas) of 0 plus or minus 16 nT. This standard deviation indicates survey-scale differences will exist in the merged data and individual anomaly differences may also be as much as –55 to 29 nT. These differences are not apparent in the total field, vertical derivative, or spectral map images but some care should be exercised in making comparisons of magnetic anomaly amplitudes across survey boundaries. Such is the case with geophysical compilations of any geophysical data with different survey parameters.

Processing of the aeromagnetic data was specifically designed for each survey and completed on the individual surveys prior to merging. Initial processing involved

gridding of the total field data using a 50 m cell size for the St. Stephen survey and 75 m cell size for the Saint John survey. Cross-line leveling errors were removed from each survey by generating a grid consisting of leveling errors and subtracting these data from the original total field survey data (i.e. de-corrugation). The leveling error grid was generated by applying a high-pass directional filter to the total field data using parameters associated with the flight-line spacing and orientation. Leveling errors are subtle in the total field data, but become very pronounced in enhanced magnetic images.

De-corrugated surveys were merged using the method described previously to form a single continuous magnetic image for the project area (Fig. 6).

3.2 Enhancement

Spectral components of the magnetic data analogous to various depths of observation were derived from the merged total field data by calculating vertical derivatives or removing short wavelength signals from the total field data. Enhanced calculated second vertical derivative of the measured magnetic total field data is shown in Figure 7. This data enhances very shallow features, generally less than 500 m, at the expense of deeper geological sources and compares most closely with mapped geological boundaries.

Short wavelength magnetic anomalies were removed from the total field data to highlight long wavelength magnetic anomalies that represent deeper geological features. A high-pass filter was used to generate a grid of shorter wavelength anomalies and these were subtracted from the total field data. High-pass filters with wavelengths of 1000, 2000, and 5000 m were generated and subtracted from the total field data to generate long

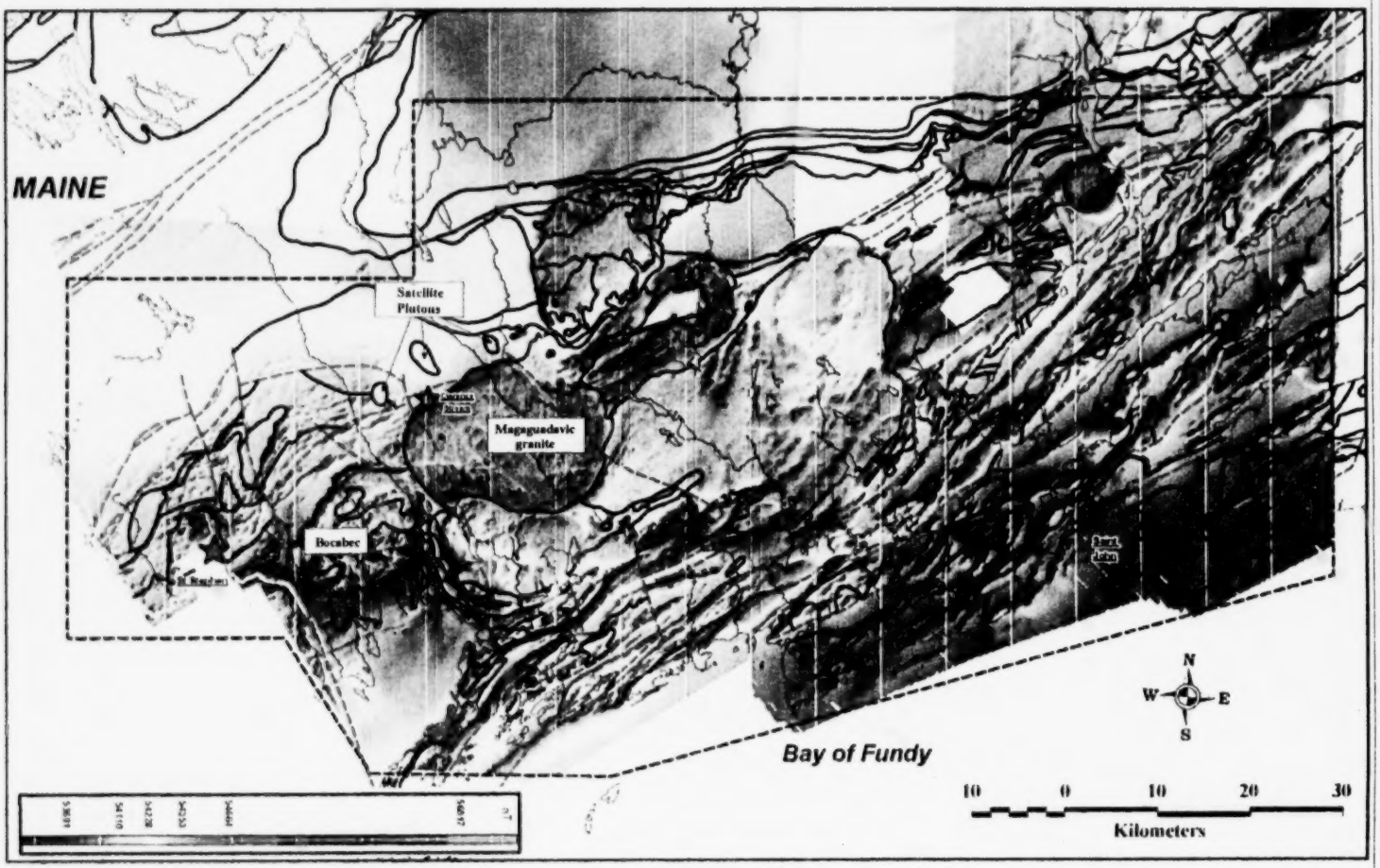

Figure 6. Colour contoured/shaded relief ($135^0/30^0$) image of magnetic total field data. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

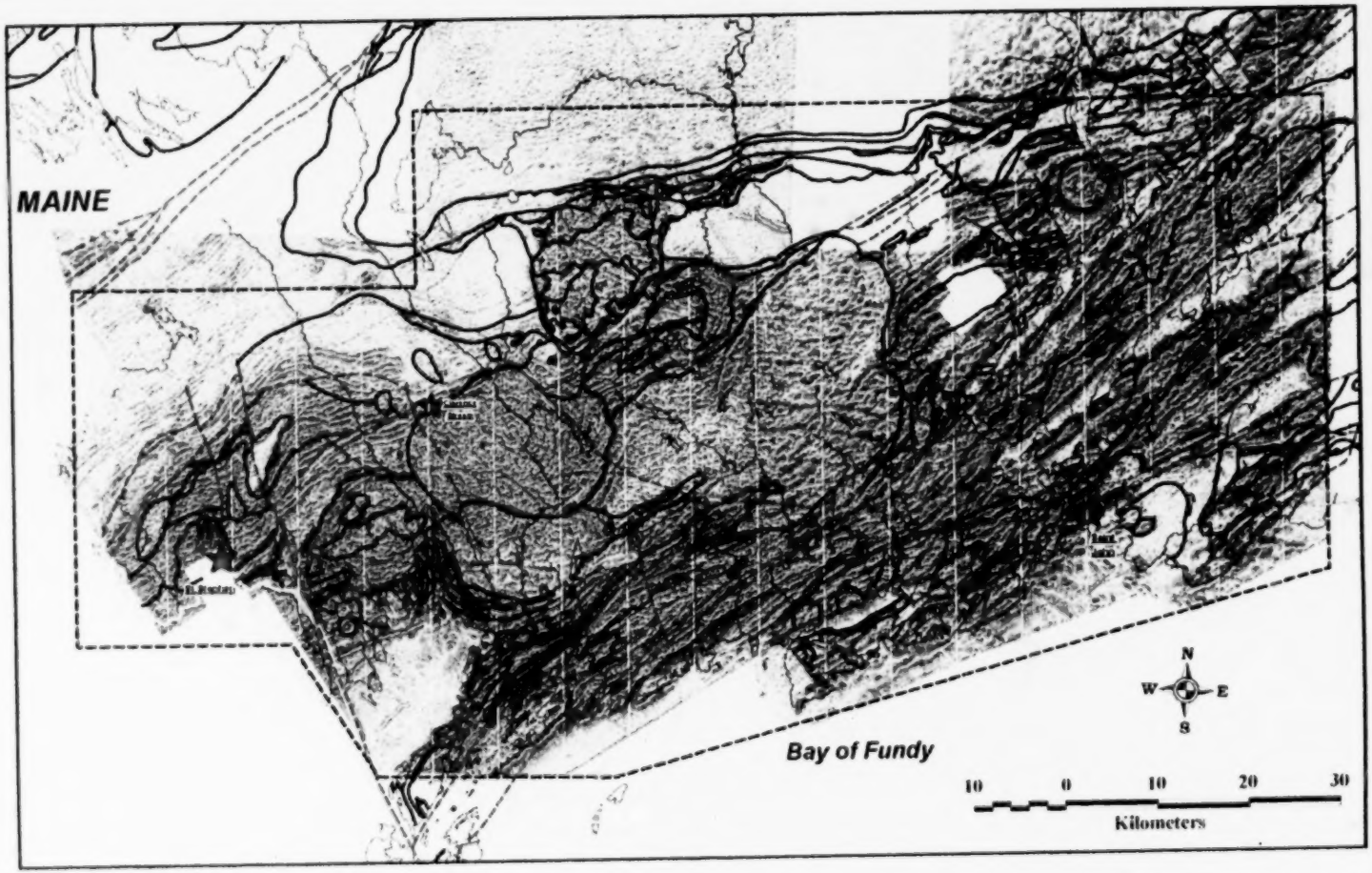

Figure 7. Colour contoured/shaded relief image ($135^0/30^0$) of enhanced magnetic data. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

wavelength map images corresponding to successively greater depths. Each resulting image then contains the magnetic signal from approximately that depth (i.e. 1000, 2000, and 5000 m) and below. In this manner various depths-of-observation can be c npared to assess how the magnetic signal changes (i.e. position and amplitude) with depth and this provides semi-quantitative information on subsurface geology. For purposes of the Southern New Brunswick Potential Fields Project, long wavelength maps were created corresponding to depths-of-observation for 1000 m and below (Fig. 8), 2000 m and below (Fig. 9), and 5000 m and below (Fig. 10).

4.0 Petrophysical Data

Petrophysical measurements (density and magnetic susceptibility) were made on approximately 2800 samples from the study area that were archived at Acadia University in Wolfville, Nova Scotia. This set included a representative suite of samples from each of the Caledonia, Brookville Kingston, and New River terranes. Approximately 60 samples from the New River belt were measured; however, most units had only one or two samples, therefore the averages are not statistically well defined. No new data are available for units in the Mascarene and St. Croix terranes and the Saint George Batholith, because those areas were not included in the Acadia University collection. During the timeframe of this project, it was not possible to acquire samples and field measurements from these units. This lack of systematic density and magnetic susceptibility measurements restricted the level of detail in the potential field model in areas underlain by these units.

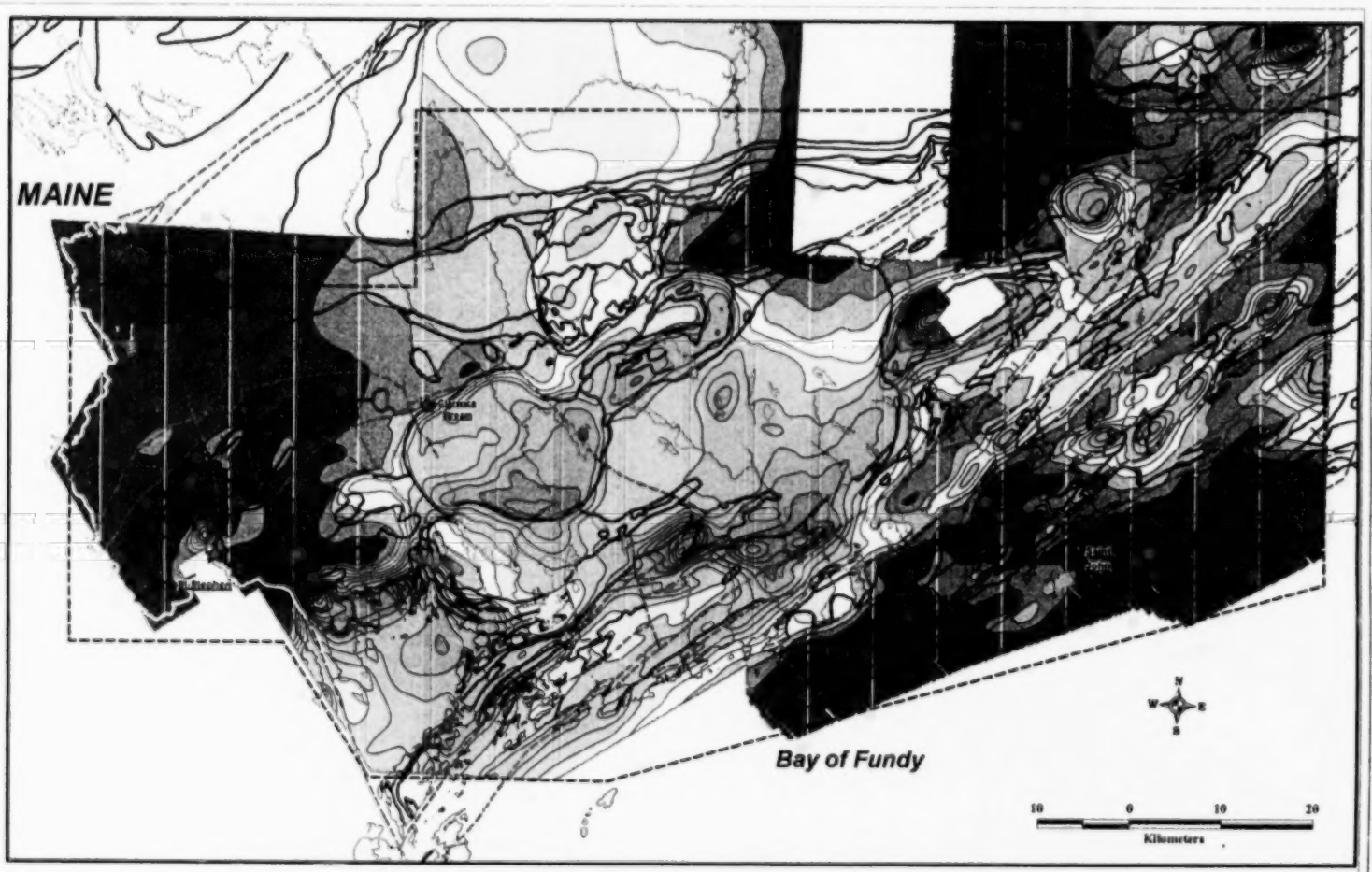

Figure 8. Colour contoured long wavelength magnetic anomaly map representing signal from 1000 m and below with 50 nT contour interval. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

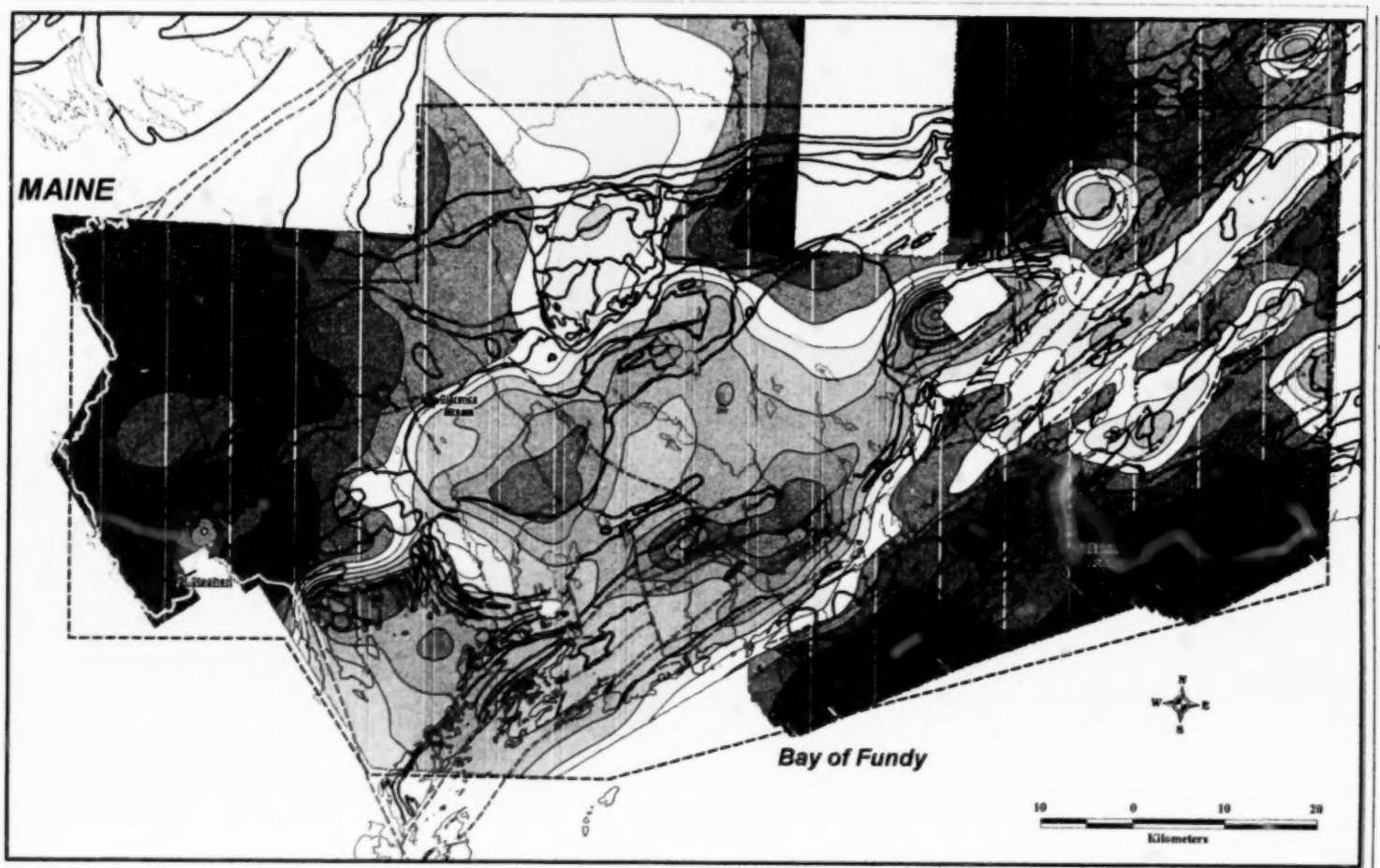

Figure 9. Colour contoured long wavelength magnetic anomaly map representing signal from 2000 m and below with 50 nT contour interval. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

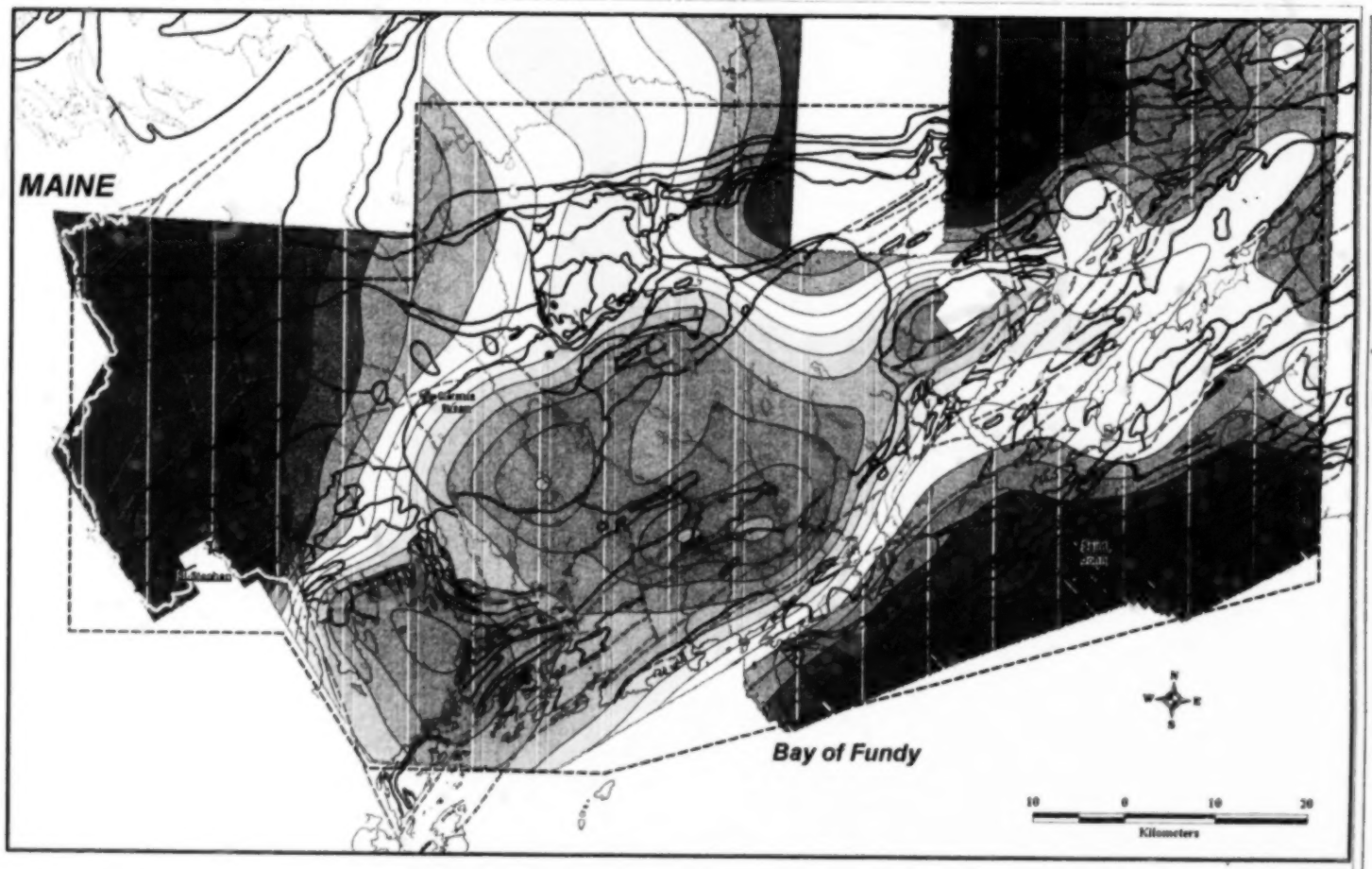

Figure 10. Colour contoured long wavelength magnetic anomaly map representing signal from 5000 m and below with 25 nT contour interval. Geology for regional images is derived from NR-5 and NR-6 (McLeod et al. 1994) and may not correspond directly with detailed mapping (e.g. 1:50 000 or better) shown in other figures.

Ranges of physical property values used in the potential field model in these areas were constrained by data compiled from Thomas and Willis (1989), and data from similar lithologies measured in the adjacent New River, Kingston, Brookville, and Caledonia terranes. Geological units shown in Table 1 were assigned on a best-estimate basis comparing figures and lithological descriptions in Thomas and Willis (1989) to regional geology (e.g. McLeod et al. 1994a,b).

Table 1. Density data for the Saint George Batholith and surrounding units, from Thomas and Willis (1989).

Unit	Affinity	Samples	Mean Density	Standard Deviation
Piskahagen Group (?)	Cover	41	2.59	+/- 0.07
Saint George Batholith	Intrusion (granite)	~100	2.61	+/- 0.02
Bocabec Gabbro	Intrusion (gabbro)	12	2.91	+/- 0.07
Flume Ridge Fm. (?)	St. Croix terrane	28	2.70	+/- 0.09
Digdeguash Fm. (?)	St. Croix terrane	31	2.77	+/- 0.06

5.0 Interpretation of Potential Field Map Patterns

Trend-enhanced gravity data and long wavelength magnetic images show a strong correlation with many of the terranes recognized in southern New Brunswick and the individual intrusive suites comprising the Saint George Batholith. Short wavelength features isolated in the enhanced magnetic data correlate with geological units and structures at the detailed map scale.

The Clarence Stream gold deposit has been described as a granite-related mineral occurrence (e.g. Thorne and Lentz, 2001; Thorne et al. 2002), and exploration by Freewest Resources Canada Incorporated had clearly defined a close association with regional structures. These phenomena are typically manifested in gravity and magnetic data as direct responses (e.g. gravity and magnetic lows) and/or indirect responses (e.g. offset of magnetic linears). Granite intrusions comprising the Saint George Batholith include a wide range of lithologies (McLeod, 1990) that are typically associated with moderate to strong amplitude, positive magnetic anomalies (Figs. 1 and 6). In contrast the gravity response is divided into strong, negative anomalies corresponding to younger, generally more felsic lithologies and moderate positive amplitude anomalies corresponding to older, generally more mafic compositions (Fig. 5). These relationships and the degree to which they vary with depth provide considerable information regarding the sub-surface lithology in the Clarence Stream area. For instance, the residual gravity data (Fig. 5) show a continuous well-developed, low amplitude negative response crossing the northern boundary of the Magaguadavic Granite and underlying the satellite plutons to the north. In comparison, the magnetic response at depths greater than 2000 m (Figs. 9 and 10) is greatly reduced from the near surface response (e.g. Figs. 6 and 7), corresponding to the mapped limits of the Magaguadavic Granite (McLeod 1990). From these comparisons, the intrusive geometry between the satellite plutons and the Magaguadavic Granite can be interpreted, in addition to the spatial extent of the satellite plutons in the sub-surface. This interpretation is examined further in the following

Figure 11. Model location with colour contoured/shaded relief image of enhanced magnetic data. Geology modified after Fyffe (1997), Fyffe et al. (1998), and McLeod et al. (1998). Shading from the southeast at 30° above the horizon. Red = higher positive values and blue = lower negative values. See text for explanation of geological units and abbreviations.

section; however, a full interpretation within the appropriate regional context is presented in Part II of the Southern New Brunswick Potential Fields project.

The association of gold mineralization at the Clarence Stream gold deposit with brittle fault zones is unequivocal (Thorne and Lentz 2001; Watters and Castonguay2002); however, understanding these structures in a regional exploration context is difficult. An enhanced, magnetic derivative image (Fig. 11) provides direct and indirect information regarding regional structural information in the Clarence Stream area. Discordant linear low-amplitude zones in the Magaguadavic Granite crosscut original magmatic patterns and display strong fabrics trending east-west, east-northeast, and northwest. Many of these magnetic features correlate with mapped faults offsetting the contact between the Magaguadavic Granite and the host sedimentary units (Fyffe 1997; McLeod et al 1998); trenching has exposed northwest-trending fractures in the units that host the Clarence Stream gold deposit. Enhanced derivative data (Fig. 11) in the Clarence Stream area also show offsets in subtle magnetic markers within and around the Main Zone, extending from the magnetic lows in the granite itself. Other breaks in magnetic patterns more closely parallel regional stratigraphy but they also correspond locally to structures associated with the Main Zone and Anomaly A. The location or extent of many regional faults (e.g. Cranberry Lake and Honeydale faults) in the area is somewhat equivocal (L. Fyffe pers. comm.); however the distribution/continuity of magnetic anomalies provides a measure of spatial control. The Sawyer Brook Fault, for instance, is well defined by a strong magnetic low that may be related to mineralizing fluids. Ambiguity in stratigraphy

may be resolved using magnetostratigraphy whereby geometry and marker horizons can be extracted from the high-resolution magnetic data.

6.0 Potential Field Model

A regional section was selected through the Clarence Stream area along Highway 127 to investigate structural and stratigraphic relationships (Fig. 12). The potential field model was constructed using data extracted from the residual gridded magnetic and gravity data described in Section 3. Residual data are those data with a first-order polynomial trend removed to isolated geological sources with wavelengths of 10-15 km or less. Petrophysical characteristics were compiled from published information (Section 4) and estimates based on comparative lithology from units in the new petrophysical database. Basement properties are derived from geophysical observations made in similar settings in the northern Appalachian orogen (e.g. Thomas and Willis 1989; Jackson et al. 1998; King 2002), published geological information (e.g. van Staal et al. 1998; Fyffe et al. 1999), and best-fit analysis. Geological control was provided by updated mapping of the area by Fyffe (1997) and Fyffe et al. (1998), and discussions with the map authors (Fig. 13).

Model fit is determined on the basis of root mean squared (RMS) error where typically "best fit" is achieved by reducing the error to 1-2% of the total dynamic range. In the case of the Clarence Stream model, the RMS error for the gravity data is less than 0.5 mGal and for the magnetic data is approximately 23 nT, implying an excellent fit.

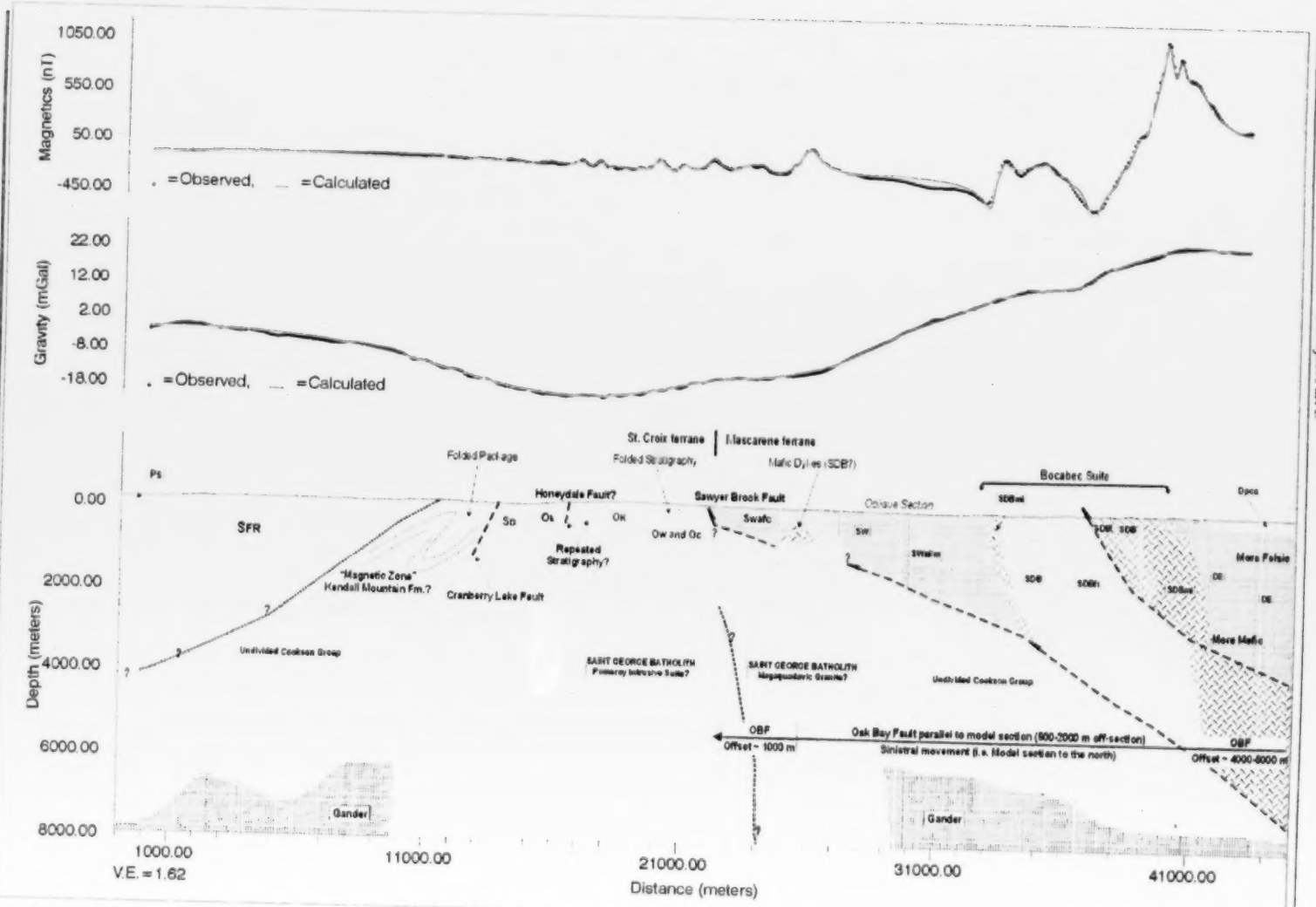

Figure 12. 2 and ¾-D potential field model for section along highway 127. See Figure 11 for location and text for explanation of geological units and abbreviations

The majority of bodies used in the model are 2-D, that is infinite strike, with the exception of some units in the Bocabec complex. These units are 2 and ¾-D, meaning that there is limited strike extent off section, where the actual amount is dictated by geological mapping. All bodies are presumed to be perpendicular to the model section; however, this is not always the case and instances where this may affect the model are identified on the section (Fig. 12).

The Clarence Stream potential field model is approximately 45 km in length and oriented roughly 175°. Appropriate geomagnetic field values are included in the model parameters and a constant elevation of 100 m was used for the magnetic data and 0 m for the gravity data. Bouguer gravity values were modeled by assigning a density of 2.67 g/cm^3 to the "air" block; corresponding to the Bouguer density used in the reduction of the observed gravity data.

6.1 Cover Units

Two areas of younger cover sequence units are present in the Clarence Stream model (Fig. 12). The northern end of the model includes a small section of Pennsylvanian (PS) sedimentary rocks (e.g. McLeod et al. 1994), and the southern end of the model contains a cover of Late Devonian sedimentary rocks assigned to the Perry Formation (DPcc; e.g. Fyffe et al. 1998). Physical properties assigned to these units are similar to those associated with Carboniferous rocks observed elsewhere the Maritimes basin (e.g. King 2001; King 2002) which have a density of 2.65 g/cm^3 or less and negligible magnetic susceptibility values.

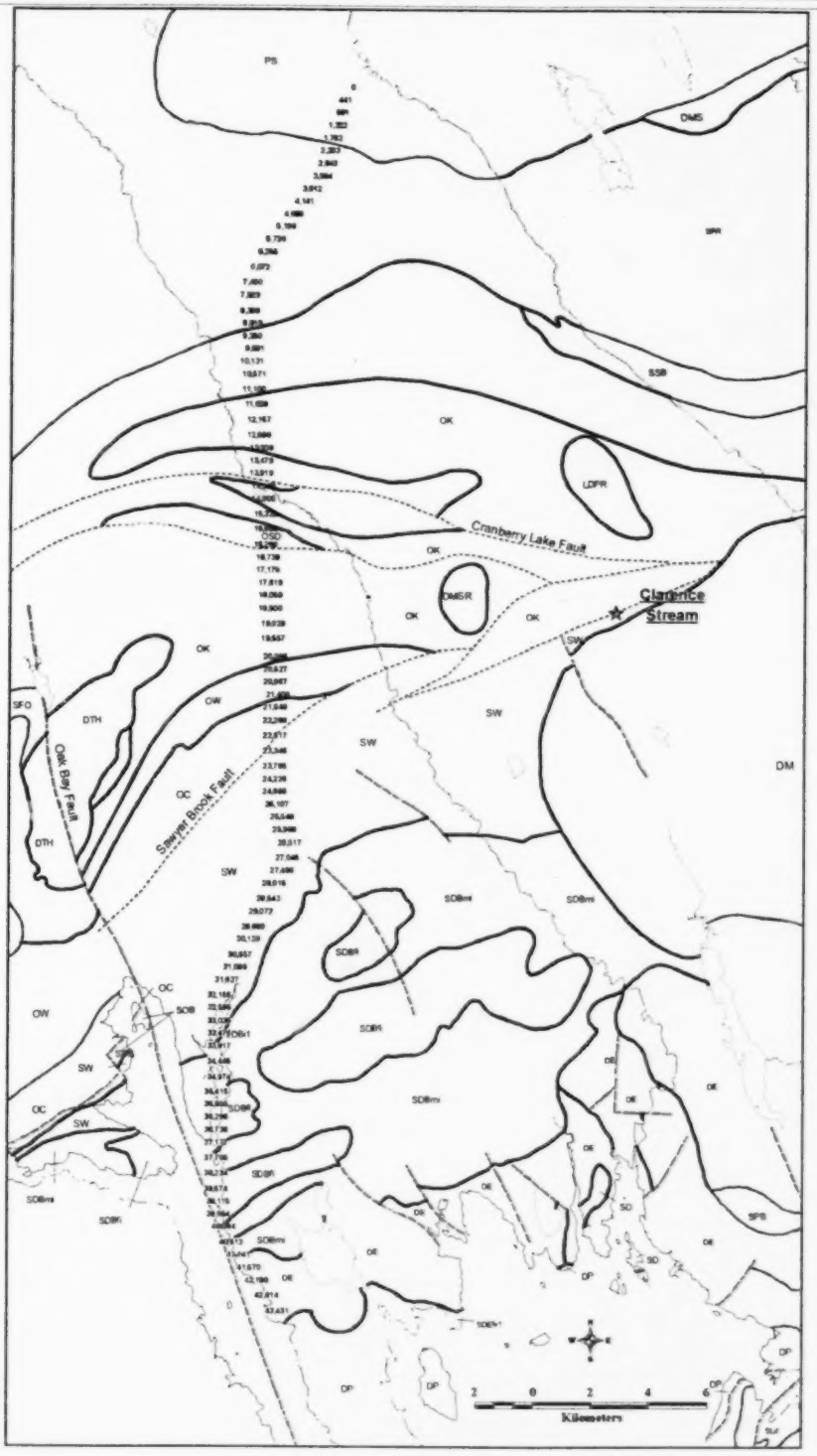

Figure 13. Model location with geology modified after Fyffe (1997), Fyffe et al. (1998), and McLeod et al. (1998).

6.2 Mascarene Terrane

The Mascarene terrane occurs in two areas separated by the Bocabec Gabbro (Fig. 12). The southern block is comprised of the Eastport Formation (DE) that is divided into more felsic and more mafic blocks generally related to units mapped in the area by Fyffe et al. (1998). The lithological division corresponds to a subtle change in density and large change in magnetic susceptibility whereby the block with lower density and susceptibility values corresponds with units dominated by felsic rocks and the block with higher density and susceptibility values corresponds to the units dominated by mafic rocks. These blocks represent approximate divisions where bulk average density values range from 2.77 – 2.79 g/cm^3 and bulk average magnetic susceptibility values range from 0.1 – 1.0 x10^{-3} SI. The second Mascarene block is comprised of rocks belonging to the Waweig Formation (SW), (Fyffe et al. 1998). Volcanic rocks with minor amounts of sedimentary rocks dominate these units. A large portion of this block (~27000-32000 m) represents an oblique section adjacent to the Bocabec Gabbro, where the model profile is essentially parallel to its contact to the east (i.e. into section). As such, the mafic dykes modeled at roughly 25,750 m may appear far removed from the Bocabec Gabbro (on section); however, in plan view as mapped by Fyffe et al. (1998) there are dykes in this area which occur less than 1000 m from the Bocabec Gabbro (SDBmi).

6.3 St. Croix Terrane

The St. Croix terrane as shown on the potential field model is comprised of rocks from the Ordovician Kendall Mountain and Silurian Digdeguash formations. A small section of rocks belonging to the Ordovician Woodland and Calais formations occur in faulted contact with Mascarene terrane units (Fyffe, 1997; Fyffe et al. 1998). The density of St. Croix units is estimated at roughly 2.67 g/cm^3 and reflects the fairly uniform sedimentary lithologies (e.g. quartz arenite, wacke, and shale) mapped by Fyffe (1997).

Interesting geophysical features in the St. Croix terrane are discrete positive magnetic anomalies associated with the Kendall Mountain Formation and a nearby, broad low-amplitude total field anomaly (~20-30 nT). This low-amplitude anomaly is not apparent on the model profile due to the large dynamic range of the magnetic field along this section; however, the total field response is best modeled by defining a "magnetic zone" to represent a package of rocks containing one or more magnetic horizons (Fig. 14). The total field data cannot easily resolve the individual responses unlike the derivative response. A projection of the magnetic layer(s) to the surface coincides with several discrete positive magnetic derivative anomalies (Fig. 11) in the Kendall Mountain Formation. These anomalies are presumably related to black shale units (L. Fyffe, pers. comm.), and may reflect repeated stratigraphy in the area as a result of complex folding (e.g. Fyffe, 1997; Castonguay et al. 2002). This magnetic unit has an estimated susceptibility of ~3.9 $x10^{-3}$ SI compared to ~0.10 $x10^{-3}$ SI for the surrounding units (e.g. Flume Ridge, SFR and undivided Cookson Group). There is little or no positive magnetic response in the area associated with the "magnetic zone" at depths greater than 2000 m

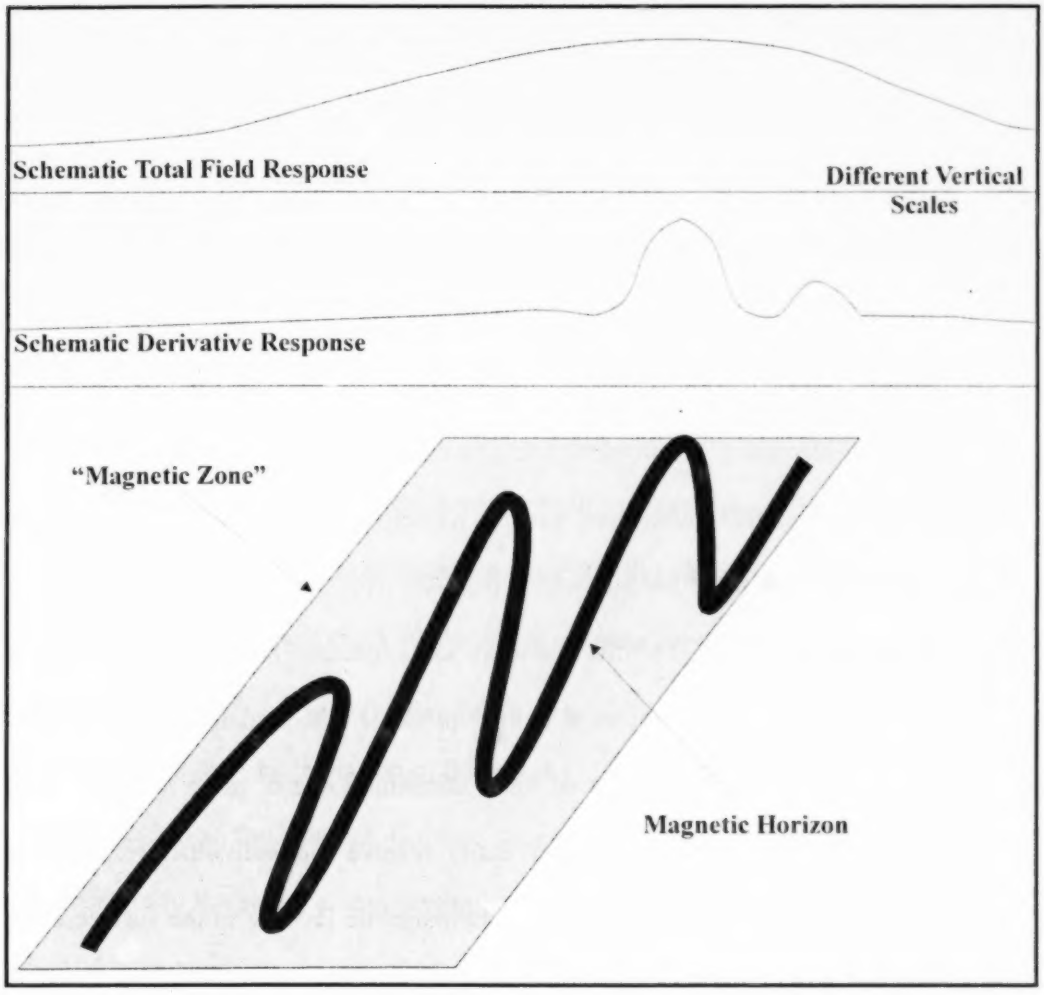

Figure 14. Schematic diagram depicting the total field and vertical derivative responses for a stratigraphic package containing tightly folded, thinly bedded magnetic rocks. No scale is implied.

(e.g. Figs. 8-10). This depth limit is similar to that derived quantitatively in the potential field model. Furthermore, the enhanced derivative data (Fig. 7) also do not show a positive low-amplitude response in this area, therefore the magnetic strata are not related to the overlying units of the Flume Ridge Formation. Another interesting feature of these

magnetic anomalies, as a group, is the definition of a north-dipping magnetic fabric in contrast to the south-dipping fabric observed south of the Sawyer Brook fault in the Mascarene terrane. This magnetic fabric is reflected in bedding and fold axial plane measurements, which dip consistently to the north along the model transect (e.g. Fyffe 1997). Most dipping contacts shown in the model (steep and flat lying) are derived by comparing the symmetry of the calculated response to that of the observed magnetic response (i.e. best-fit analysis). Due to the inclination of the earth's geomagnetic field, traverses in a north-south direction generate a slightly bi-polar or asymmetric response over magnetic bodies. This is manifested as a positive peak with a low immediately adjacent to the north. This asymmetry in the measured response and the response associated with dipping magnetic bodies constrains the orientation of magnetic contacts in a fairly unambiguous manner and where these profile shapes are consistent in orientation or asymmetry over a given area they define a magnetic fabric.

The significance of the magnetic phenomena identified in the St. Croix terrane with respect to regional tectonic interpretations has not been investigated in detail.

6.4 Saint George Batholith

The model section on Highway 127 crosses exposures of the Bocabec Gabbro, passes to the west of the Magaguadavic Granite, and through the linear belt of small satellite plutons on the northern margin of the Saint George Batholith (e.g. McLeod 1990; Fyffe 1997; Fyffe et al. 1998; McLeod et al. 1998).

The Bocabec Complex occurs roughly between 32,000 m and 42,000 m on the modeled section (Figs. 12, 13) and comprises a wide range of lithologies as mapped by

Fyffe et al. (1998) and McLeod (1990). They include gabbroic rocks (SDBmi), and pink medium-grained, hornblende granite (SDBfi), and other mixed compositions (SDB). Petrophysical data associated with the Bocabec Gabbro (Table 1) only reflect density values associated with the most mafic compositions, whereas the model crosses multiple compositions ranging from granite to gabbro (Fig. 13; Fyffe et al. 1998).

Typically the gabbroic rocks have a high density and magnetic susceptibility whereas granitic rocks typically have lower density and magnetic susceptibility values. The range of density values for the Bocabec Gabbro in the potential field model is 2.72 – 2.86 g/cm^3 and corresponding magnetic susceptibility values range from ~8 – 60 x10^{-3} SI. These units are represented in the model (Fig. 12) as SDBfi (2.72 g/cm^3), SDB (2.76 g/cm^3), and SDBmi (2.81-2.86 g/cm^3), and the susceptibility values are positively correlated with the density values.

The Bocabec Gabbro appears to have been cut at depth by a low-angle fault, which offsets the upper portion of the mafic unit to the northwest. There is evidence for this type of structure from regional geological interpretations (Fyffe et al. 1998; Fyffe et al. 1999) and magnetic map patterns (Section 5.0). This structure may be related to sinistral movement along the Oak Bay Fault as it accommodates the reduction in map displacement along the Oak Bay Fault from an estimated 4000 – 5000 m along coastal sections to ~1000 m near the middle of the model section. This interpretation is also consistent with Thomas and Willis (1989), who modeled the Bocabec Gabbro, using gravity data only, as an isolated near-surface body. The new magnetic data support their interpretation; however, processing and enhancement of the magnetic data (Figs. 8-10)

show a marked migration (i.e. lateral displacement of a positive magnetic peak) in the response associated with the Bocabec Gabbro. The positive response is offset to the southeast with each deeper (i.e. longer wavelength) spectral component, which is consistent with a low-angle structure offsetting the magnetic gabbroic unit(s) in the manner shown in the model.

The Magaguadavic Granite is clearly identified in magnetic map patterns as a spatially extensive moderate- to high-amplitude, positive feature (Fig. 6). However, longer wavelength components of the total field magnetic data (e.g. Figs. 9 and 10) show a migration in the peak positive magnetic response to the south, concentrating along the southern edge of the body at depths greater than 5000 m. The corresponding gravity data (Fig. 5) show a pronounced gravity low beneath the northern half of the Magaguadavic Granite and the satellite plutons to the north. These data are interpreted as a subtle change in density and susceptibility whereby a more felsic granite has intruded into the Magaguadavic Granite and extends to the north beneath the satellite plutons. This interpretation is consistent with Thomas and Willis (1989) in which they interpreted the satellite Sorrell Ridge, Pleasant Ridge, and Beech Hill plutons to be underlain by a common granitic source at a depth of roughly 1200 m.

6.5 Basement Unit

The basement unit interpreted to underlie the modeled section along highway 127 is comprised of homogeneous high density (2.81 g/cm^3) and high susceptibility (35 x10^{-3} SI) rocks. These values are broadly characteristic of the composite Gander composite terrane (e.g. Jackson et al. 1998; van Staal et al. 1998), and are in contrast to those of

basement units associated with the adjacent Bras d'Or - Brookville terrane or the Avalon (Mira, Caledonia) terrane (e.g. Loncarevic et al. 1989; Jackson et al. 1998; King 2002; King and Barr, press). A summary of differences in bulk density and susceptibility derived from quantitative analysis by King and Barr (in press) and King (2002) are presented in Table 2. A more detailed analysis of the tectonic implications of these data will be presented in a separate discussion currently in preparation by the authors.

Table 2. Comparison of physical properties for basement units in the northern Appalachian Orogen.

Terrane (Basement)	Density (g/cm^3)	Susceptibility ($x10^{-3}$ SI)
Avalon	2.81	0.5-0.8
Brookville - Bras d'Or	2.72	2-6
Gander Composite	2.81	25-45

7.0 Conclusions and Recommendations

The compilation and interpretation of potential field data in plan and sectional view has provided valuable insight into the sub-surface structure and stratigraphy in the Clarence Stream area. Magnetic fabrics have been recognized which may be related to regional structural events, and individual structures consistent with geological trends have been identified. Tectonic implications regarding basement and terrane distribution in the area have also been addressed by utilizing long-wavelength map pattern data and interpretations from the potential field model. These interpretations support a single basement, most likely Gander-related based on interpreted density and magnetic

susceptibility, underlying the section. This interpretation is consistent with results from modeling along strike to the north, the results of which will be offered in a separate presentation (King and Barr, in prep), and results found in Cape Breton Island.

The potential field data were particularly useful in delineating a more felsic granite component of the Saint George Batholith underlying the Clarence Stream gold deposit and surrounding area at depth (Figs. 11 and 15). This low-density body is interpreted to intrude the northern part of the Magaguadavic Granite and to extend northward beneath the satellite plutons along the margin of the Saint George Batholith. The low magnetic response associated with this younger more felsic granite clearly shows its distribution broadening with depth (Figs. 9 and 10). This more felsic phase of the Magaguadavic Granite may represent a more fractionated component of a long-lived magmatic and hydrothermal system that generated gold mineralization at various depths along the northern margin of the Saint George Batholith. Residual gravity anomalies within the low magnetic zone isolate the response associated with the satellite Pleasant Ridge and Sorrel Ridge plutons (Fig. 15). These complex intrusive events within the Saint George Batholith, demonstrated at surface and in the subsurface, likely generated several episodes of mineralizing fluids at various depths over a period of approximately 30 million years (Thorne and McLeod 2003).

Based on the compilation and interpretation of regional potential data, several recommendations can be made regarding enhancements to future work or industry exploration programs.

Figure 15. Model location with colour contoured residual Bouguer gravity. Contour interval is 2 mGal and magenta-red are higher positive values whereas blue-cyan represents lower negative residual Bouguer values. Geology modified after McLeod (1994)

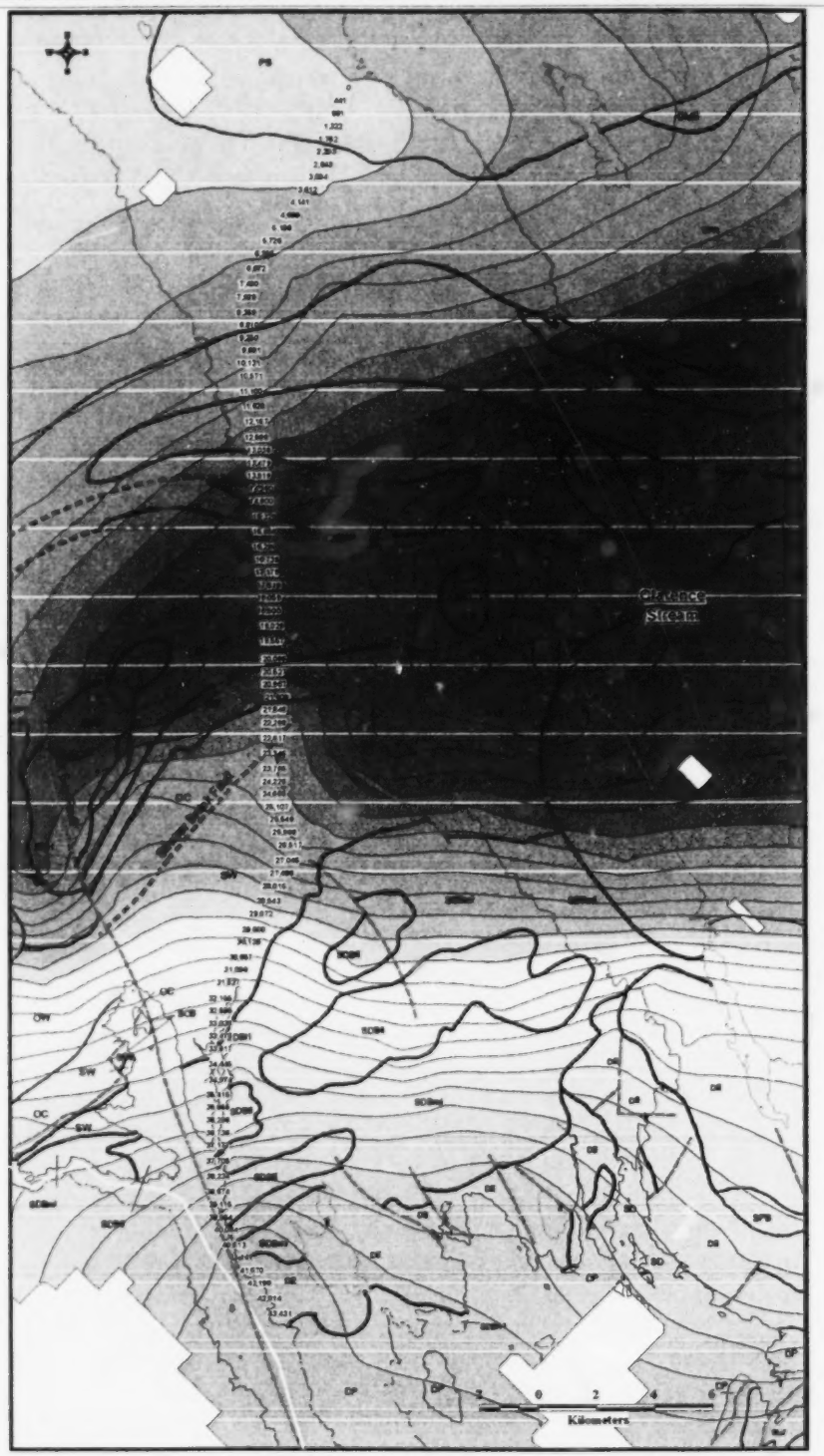

Figure 15. Model location with colour contoured residual Bouguer gravity. Contour interval is 2 mGal and magenta-red are higher positive values whereas blue-cyan represents lower negative residual Bouguer values. Geology modified after McLeod (1994).

1. A clear correlation between mapped plutons and gravity anomalies has been demonstrated, and new gravity data delineate the sub-surface extent of the satellite plutons along the northern margin of the Saint George Batholith. Therefore, new gravity surveys could be used to map near-surface (<1000 m depth) intrusions having the potential to drive gold-mineralizing fluid systems like that controlling the Clarence Stream deposit.
2. New models should be constructed in several orientations to develop a three-dimensional (3-D) image of the structure and stratigraphy in the Clarence Stream area. These models could be used to identify settings like the Clarence Stream gold deposit, which may have similar spatial relationships with shallow intrusions.
3. Potential field models can be used to identify magnetostratigraphy and resolve complex structures (e.g. repeated stratigraphy) in the Kendall Mountain and Digdeguash formations in the Clarence Stream area. Magnetic markers identified in the potential field model (Figs. 11, 12) near the Clarence Stream gold deposit appear to show repetition and geophysically interpreted geometry, from magnetic profile asymmetry, correspond well to published structural data.
4. The physical property database should be expanded to include samples from the Mascarene and St. Croix terranes and various suites in the Saint George Batholith. These data would greatly enhance the modeling process and provide more accurate interpretations. Data could be collected from samples in storage, drill

core, or in the field on outcrops (i.e. susceptibility) using 1:50,000 maps published by the New Brunswick Department of Natural Resources.

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